OCR
Oxford Cambridge and RSA

Friday 24 May 2024 – Morning

Level 3 Cambridge Technical in Engineering

05822/05823/05824/05825/05873 Unit 4: Principles of electrical and electronic engineering

Time allowed: 1 hour 30 minutes
C304/2406

C304/2406

You must have:
- the Formula Booklet for Level 3 Cambridge Technical in Engineering (inside this document)
- a ruler (cm/mm)
- a scientific calculator

05822 – 04

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

Date of birth | D | D | M | M | Y | Y | Y | Y |

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working.
- Give your final answers to a degree of accuracy that is appropriate to the context.

INFORMATION
- The total mark for this paper is **60**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **16** pages.

ADVICE
- Read each question carefully before you start your answer.

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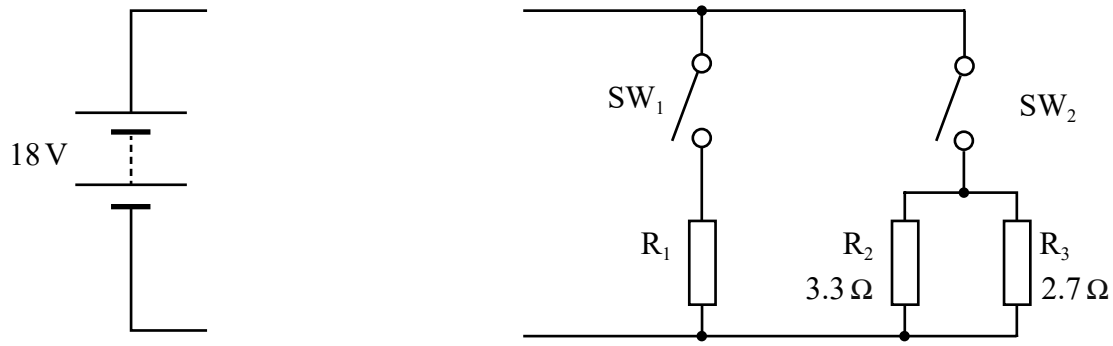
1 An incomplete circuit diagram of an electric heater is shown below.



(a) Complete the circuit diagram so that current flows through the resistors when switches SW_1 and SW_2 are closed.

Include an ammeter and a voltmeter in the circuit to measure the circuit current and the battery voltage.

[2]

(b) Calculate the current though R_2 when switch SW_2 is closed.

Current through R_2 = ... A **[1]**

(c) Calculate the power dissipated by R_2 when switch SW_2 is closed.

Power in R_2 = ... W **[1]**

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(d) Calculate the combined resistance of R_2 and R_3 in parallel.

Resistance of R_2 and R_3 in parallel = ... Ω **[2]**

(e) When switch SW_1 is closed and switch SW_2 is open the power dissipated in R_1 is 1.1 kW.

(i) Calculate the value of R_1.

Value of R_1 = ... Ω **[2]**

(ii) Calculate the energy dissipated by R_1 when the switch is turned on for 8 minutes.

Give the units for your answer.

Energy = ... **[3]**

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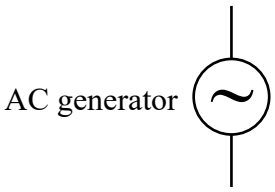
2

(a) What is 'a simple AC generator'?

.....

..... **[1]**

(b) The diagram below shows a simple AC generator symbol.



Draw on the diagram to show a 330 Ω resistor and a 6.8 μF capacitor connected in series with the AC generator.

Label the resistor and the capacitor with their values.

[2]

(c) The AC generator produces a sine wave of frequency 120 Hz.

(i) Calculate the reactance of the capacitor (X_C) at 120 Hz.

Reactance of capacitor (X_C) = ... Ω **[2]**

(ii) State the reactance of the resistor at 120 Hz.

Reactance of resistor = ... Ω **[1]**

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(iii) Calculate the impedance of the resistor and capacitor in series at 120 Hz.

Impedance of resistor and capacitor = ... Ω **[2]**

(iv) Calculate the phase angle ϕ between the voltage from the generator and the current through the resistor and capacitor.

Give the units for your answer.

ϕ = ... **[2]**

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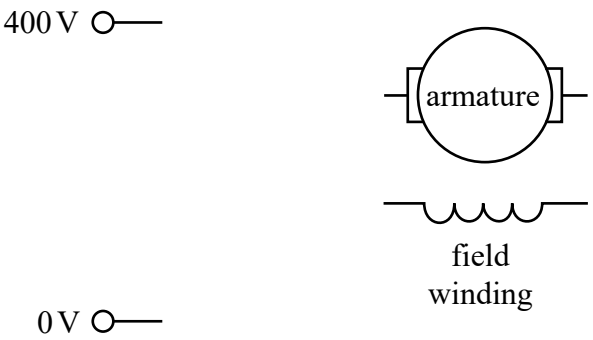
3 A factory uses a conveyor belt to move parts to a packaging machine at a steady speed.

(a) A shunt-wound DC motor is used to operate the conveyor belt in the factory.

The motor is operated from a 400 V power supply.

(i) Draw on the diagram below to show how the field winding and armature in a shunt-wound DC motor should be connected to a 400 V power supply.



[1]

(ii) Suggest why a shunt-wound DC motor was used for the conveyor belt rather than a series-wound DC motor.

.....

.....

.....

..... **[2]**

(iii) The field winding has a resistance (R_f) of 10 kΩ.

Calculate the current in the field winding (I_f) when it is connected to the 400 V supply.

I_f = ... A **[1]**

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(iv) The armature has a resistance (R_a) of 12 Ω.

When the motor is running at full speed the current in the armature (I_a) is 2.0 A.

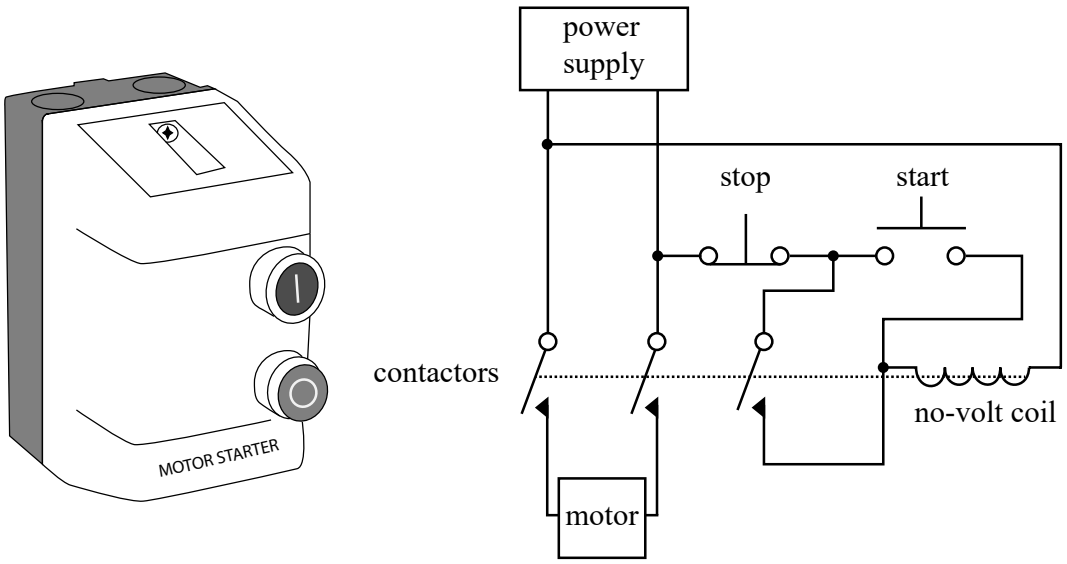
Calculate the EMF (E) in the shunt-wound DC motor when the motor is connected to the 400 V supply and running at full speed.

Give the units for your answer.

E = ... **[3]**

(b) The motor for the conveyor belt is controlled by a motor starter containing a no-volt coil.

The diagram shows the motor starter and its circuit diagram.



Complete the sentences below using the most appropriate word in each gap.

Choose words from the following list.

Each word may be used once, more than once or not at all.

oscillating **reversed** **stopped** **turning**

When the start switch is pressed, the motor starts turning. After the switch is released, the motor is ..... .

The motor is turning when the power supply fails and provides no power to the motor for 15 minutes. After the power supply is restored, the motor will be ..... .

[2]

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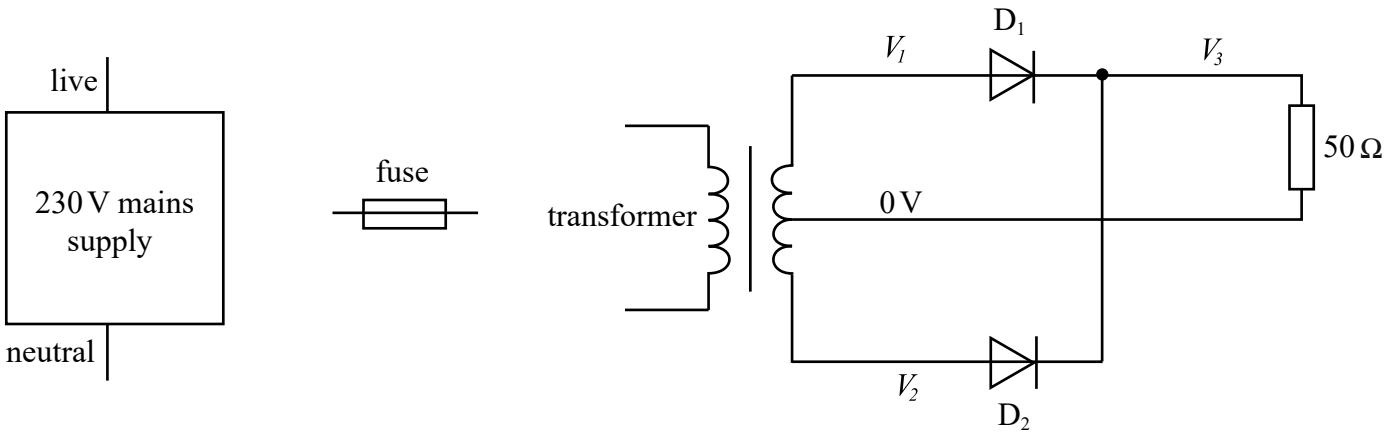
4 The diagram below shows an incomplete circuit diagram for a power supply.



(a) The circuit is protected by a fuse.

(i) Draw on the diagram above to show how to connect the 230 V mains supply, fuse and transformer.

[2]

(ii) Explain how the fuse protects the circuit.

.....

.....

.....

..... **[2]**

(iii) Circuit breakers are sometimes used instead of fuses.

State **one** advantage of using a circuit breaker instead of a fuse.

.....

..... **[1]**

(b) The diodes in the power supply form a rectifier.

(i) State the purpose of the rectifier in a power supply.

.....

..... **[1]**

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(ii) Which of the sentences most appropriately describes the state of the diodes in the power supply when $V_1 = +55\,V$ and $V_2 = -55\,V$?

Tick (✓) **one** box.

Both D_1 and D_2 are conducting ☐

D_1 is conducting but D_2 is not conducting ☐

D_2 is conducting but D_1 is not conducting ☐

Neither D_1 nor D_2 are conducting ☐

[1]

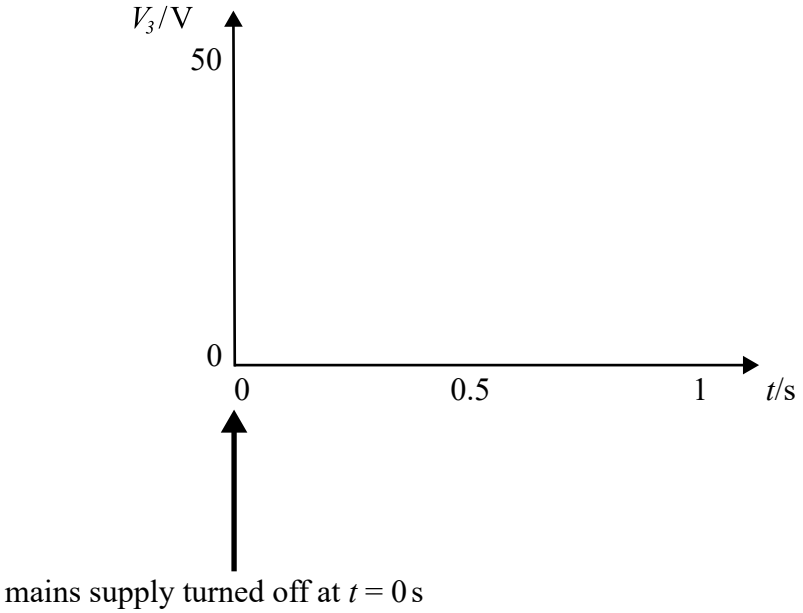
(c) A 2200 μF capacitor is added to the circuit in parallel with the 50 Ω resistor to smooth the output of the power supply.

(i) Calculate the time constant (τ) of the RC circuit.

τ = ... s **[1]**

(ii) Sketch a graph below to show how the voltage across the capacitor (V_3) changes with time (t) when the mains supply to the power supply is turned off.

The voltage V_3 is 50 V when the mains supply is turned off at time $t = 0\,s$.



[2]

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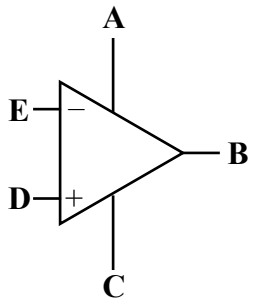
5 The diagram below shows the symbol of an operational amplifier (op-amp).



(a) Identify the connections on the op-amp by putting the appropriate letters in the answer spaces.

Input connections: ..... and ..... .

Output connection: ..... .

Supply voltage connections: ..... and ..... .

[2]

(b) Draw a line in the diagram below to join each behaviour of an op-amp to the most appropriate characteristic of an op-amp.

There will be one characteristic with no connecting line.

Behaviour of an op-amp	Characteristic of an op-amp
	High input impedance.
A significant current can flow into or out of B.	
	Low output impedance.
The current into or out of E is always very small or zero.	
	Single-ended output.

[2]

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(c) An inverting op-amp is used to amplify the signal from a temperature sensor.

The voltage gain of the inverting op-amp is −12.

The formula for the voltage gain of an inverting op-amp is:

$$Voltage\ Gain = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

(i) Calculate the output voltage (V_{out}) of the op-amp when the signal from the temperature sensor is 0.3 V.

Output voltage (V_{out}) = ... V **[1]**

(ii) Draw the circuit diagram of an inverting op-amp with a voltage gain of −12.

Label all components with suitable values.

Draw the connections to the 0 V, output and temperature sensor.

[5]

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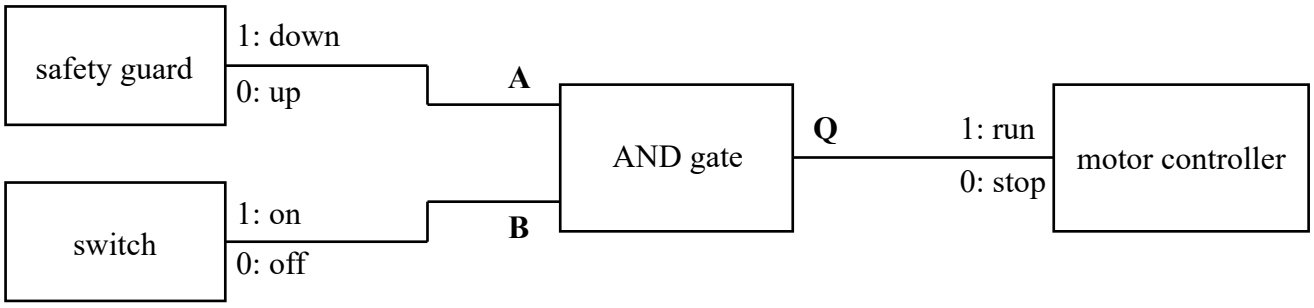
6

(a) The block diagram below shows a digital electronic circuit to control the motor in a drill.



(i) State what 'digital electronic circuit' means.

.....

..... **[1]**

(ii) Give an example from the diagram to show that this is a digital electronic circuit.

.....

..... **[1]**

(b) Draw the symbol for an AND gate in the space below.

[1]

(c) Draw the truth table for an AND gate.

Label the columns in your truth table **A**, **B** and **Q**, where **Q** is the output.

[2]

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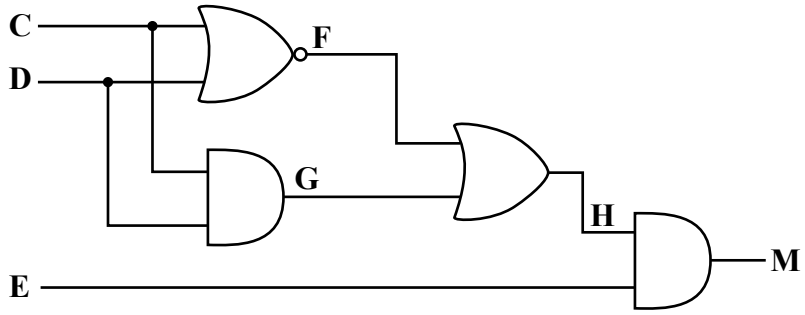
(d) Describe the conditions needed for the motor to run.

.....

..... **[1]**

(e) The diagram below shows a logic circuit.



Complete the truth table for the logic circuit.

C	D	E	F	G	H	M
0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

[4]

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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